ABSTRACT AND REFERENCES

APPLIED MECHANICS

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DETERMINING THE EFFECTIVE CHARACTERISTICS OF A COMPOSITE WITH HOLLOW FIBER AT LONGITUDINAL ELONGATION (p. 6-12)

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When solving problems on the mechanics of composites, it is convenient to use a composite model in the form of a continuous homogeneous medium with effective constants, which adequately reflect its most essential characteristics. Modern engineering and construction commonly use the composites, reinforced with hollow fibers. Unknown for today are the analytical dependences for the effective elastic constants of such composite materials with transtropic components. The task on constructing such dependences is resolved in this paper.

We have derived analytical dependences for the effective longitudinal modulus of elasticity and the Poisson's coefficient in the unidirectional fiber composite, consisting of a transtropic matrix and hollow fiber. The composite is simulated by a solid uniform transtropic material. The conditions for a perfect connection are satisfied at the interphase surfaces. In order to obtain the analytical dependences, we have solved two boundary problems: on the longitudinal elongation of a composite cylinder, whose components are the transtropic matrix and hollow fiber, and a solid homogeneous cylinder that models the transtropic composite. The application of conditions for displacements alignment and stresses, found by solving these problems, provided an opportunity to derive formulae for the effective longitudinal modulus of elasticity and Poisson's coefficient. These formulae reflect the dependences of effective characteristics of a composite on elastic characteristics of the matrix, fibers, and volumetric shares of the fiber and the cavity inside it.

We have compared results of calculations using the formulae derived with the calculation results based on previously known ratios for the isotropic ratios. This comparison has shown that their relative deviation does not exceed one percent. Application of the obtained dependences makes it possible to design structures with elements made from the composite materials.

Keywords: unidirectional fibrous composite, longitudinal elongation, hollow fiber, effective elastic constants

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DETERMINATION OF STRESSES AND STRAINS IN THE SHAPING STRUCTURE UNDER SPATIAL LOAD (p. 13-18)

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The computational model of the machine – environment system, taking into account the mutual influence of the working body and compaction mixture was developed. It is based on the condition of determining the contact forces of interaction between the subsystems and estimation of the ratio of the time of action and time of wave propagation. This approach is new, since it takes into account the real relationship between the dynamic parameters of the machine and the environment and degree of interaction. The study and determination of stresses and strains in time confirmed the hypothesis of their significant influence on the process. A fundamentally new result was revealed, which consists in the fact that the transition process should take into account the determination of parameters and locations of vibrators. The laws of stress and strain variations during spatial oscillations of the shaping surface were established. Modes of natural oscillations of the system are implemented with higher oscillation amplitudes and correspondingly lower frequency. And this opens up a real opportunity to reduce the energy intensity of the vibration machine. Numerical values of stresses and the nature of their distribution in the shaping surface, depending on the angle of the instantaneous action of the external force of vibrators, the presence of bending and torsional oscillations were obtained.

So under the condition of two excitation forces, the points of application of which are displaced relative to each other by ½ of the length of the structure, placing the force application points symmetrically at a distance of ¼ of the size of the structure on both sides allowed obtaining cophased and anti-phase directions of stresses and acting external force.

In calculations of vibration machines using shaping surfaces, it was proposed to take into account output numerical values of the amplitude-frequency mode of the oscillation exciter. Practical recommendations for the rational design of sections of shaping structures were developed and technological parameters were determined. To construct such shaping structures, the installation sites for vibrators were determined. The results obtained can be successfully used in related processes, for example, in the mining industry, as active surfaces for ore transportation, for the transfer of suspensions and solutions in the chemical industry.

Keywords: computational model, shaping structure, spatial load, stress-strain state, concrete mix.

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IMPROVING A METHODOLOGY OF THEORETICAL DETERMINATION OF THE FRAME AND DIRECTING FORCES IN MODERN DIESEL TRAINS (p. 19-25)

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The method for determining the directing force was improved, taking into consideration the effect of transverse creep forces and the angle of the directing force inclination to the vertical axis.

It was established that when determining the directing force, it is necessary to check the gap between the wheel flange and the rail head which is difficult to realize without computer simulation.

When determining the frame force on the axle of the wheel set, a comprehensive approach was adopted taking into account geometric irregularities of the track path, both in vertical and horizontal planes; longitudinal and transverse creep forces at the point of the wheel-rail contact and influence of adjacent wheel sets of the diesel train car.

Dependences of the frame and directing forces on speed of the carriage movement and the value of amplitude of the horizontal irregularity of the rail track were obtained. It was established that when moving in the straight section of the track, an increase in speed from 0 m/s to 50 m/s results in a rise in the value of the frame force: up to 8.3 kN for the first wheel set and 19.37 kN for the second wheel set and the directing force up to 31.38 kN for the first wheel set and up to 46.83 kN for the second wheel set. The increase in amplitude of the horizontal irregularity of the track, which is one of the primary causes of occurrence of forced oscillations of the carriage section above the springs also leads to an increase in numerical values of the forces of interaction of the rolling stock with the rail track. All this can bring about an increased power influence of the wheel set on the track and a negative impact on the basic criteria of traffic safety.

Influence of the carriage movement speed on the value of transverse creep forces was studied. It has been established that with an increase in the carriage speed from 0 m/s to 50 m/s, these forces grow from 0 to 15.75 kN for the 1st wheel set and from 0 to 29.22 kN for

the 2nd wheel set. This indicates impermissibility of neglecting the transverse creep forces when determining the directing force.

Comparison of numerical values of the directing force determined by different methodologies was performed. It has been established that the methodology used in conducting forensic examination of railroad accidents may result in underestimation of fulfillment of the derailing condition. At the same time, calculations according to the formula improved in this study give an opportunity to obtain the results most approximate to the real operation conditions.

Comparison of the experimental and theoretical calculated values of the frame force acting on the first wheel set of the diesel train car was made and their practical coincidence was shown. Discrepancy of the compared values of the frame force was within 7.2 %.

Keywords: diesel train, frame force, wheel set, directing force, railroad, irregularity.

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IMPROVEMENT OF THE STRUCTURE OF FLOATING DOCKS BASED ON THE STUDY INTO THE STRESSED-DEFORMED STATE OF PONTOON (p. 26-31)

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We have investigated the stressed-deformed state of reinforced concrete slabs of the composite dock pontoon with a reduced number of framing sets. A refined estimation scheme was applied in the calculation of bending plates of the slipway-deck and pontoon bottom, which accounts for the work of reinforcement structure in both directions. Accounting for the work of reinforcement structures in both directions makes it possible to accurately estimate the structural strength and provide recommendations on their design in terms of material consumption and optimal size. When modeling work of

concrete, we took into consideration that concrete at stretching has a less rigidity for stretching than for compression.

It has been shown that the developed design and construction technology of the composite dock with a reduced number of framing sets in the pontoon makes it possible to expand the technological capabilities of dock construction. The results derived from the calculations of cumulative stresses in the slabs of the dock's pontoon stack-deck showed that the actual safety factors meet the requirements for strength. Given that the structure of concrete slabs perceives the moment of resistance that is several times larger than that of steel, it becomes possible to increase the span of a slab and to erect less supports-bulkheads. The result would be the reduced material costs and the decreased labor intensity of operations at dock construction.

We have proposed a structure and a construction technology for a composite dock with a reduced number of framing sets in the pontoon. It has been shown that the erection of transverse bulkheads between the inner boards in 4 quadrats, that is, in 3 meters, as well as the absence of lack frames, and floors and beams, in concrete towers, makes it possible to reduce the amount of materials, as well as bring down the labor intensity of dock construction. This paper lists features for the selection of shipbuilding concrete intended to withstand extreme operating conditions of marine reinforced-concrete structures.

Keywords: floating composite dock, dock construction technology, reinforced-concrete sections, pontoon, strength of reinforced-concrete slabs.

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DEVELOPMENT OF DIMENSIONALLY STABLE STRUCTURES OF MULTILAYER PIPELINES AND CYLINDRICAL PRESSURE VESSELS FROM CARBON FIBER REINFORCED PLASTIC (p. 32-38)

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In the framework of the momentless theory of cylindrical thin shells, the elastic deformation of multilayer pipes and pressure vessels is investigated. It is assumed that the pipes and pressure vessels are made by two-way spiral winding of carbon fiber reinforced plastic tape on a metal mandrel.

The analysis of the dependences of elastic deformations on the reinforcement angles is performed. The relations for axial and circumferential deformations of the wall, depending on the structure of the layer package, reinforcement angles under static loading are obtained. The separate and combined effect of internal pressure and temperature is considered. For the separate effect of loads, the graphs of deformations against the winding angle are plotted.

Composite pipes made of KMU-4L carbon fiber reinforced plastic, as well as composite metal-composite pipes, are investigated. The results obtained for thermal loads are in good agreement with the data of the known experiment and solution. Depending on the load parameters, composite and metal-composite structures with dimensionally stable properties are determined.

It is shown that dimensionally stable structures can be used to solve the problem of compensation of elastic deformations of pipelines. For this purpose, using the ASCP software package, the variant analysis of model structures is performed. By the comparative analysis of the three versions of the structure, layer package structures and reinforcement schemes, ensuring a significant reduction of loads on the supporting elements are obtained. On the example of a pipeline with a flowing fluid, it is shown that the use of dimensionally stable multilayer pipes makes it possible to eliminate bending deformations and significantly reduce the level of working forces and stresses.

Dimensionally stable composite multilayer pipes open up new approaches to the design of pipelines and pressure vessels. It is possible to create structures with predetermined (not necessarily zero) displacement fields, consistent with the fields of the initial technological displacements, as well as with the displacements of conjugate elastic elements and equipment when the operating mode changes. The scope of such structures is not limited to "hot" pipes. The results can be used in cryogenic engineering.

Keywords: composites, carbon fiber reinforced plastic, carbon fibers, reinforcement schemes, pipeline designs, dimensional stability, elastic deformations.

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CONSTRUCTION OF A MODEL FOR THE DISTRIBUTION OF RADIAL LOAD AMONG THE BEARING'S ROLLING BODIES (p. 39-44)

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We have proposed analytical and computer models related to the distribution of radial load among the rolling bodies in a single-row radial bearing.We have analyzed patternsin the geometry and deformation of parts, as well as gaps in the bearing without taking into consideration the different positions of centers of the inner and outer rings. The latter can significantly affect the distribution of radial load among rolling bodies and cause the slippage of rolling bodies on rings.

The present study aims to refine the estimated value of load distribution among the bearing's rolling bodies. The closer the result of calculation of load distribution, especially, on the central rolling body, to the actual value, the more accurately the resourceis determined. That largely defines the reliability of a machine, as well as the cost of repair and replacement of bearings. It is equally important when determining the fatigue strength and durability of the separator to know as accurately as possible the magnitudes and directions of action of radial forces on the rolling bodies at the edges of the bearing's loading zone. It is these forces that determine the loads acting on the separator.

We have constructed geometrical equations that link the radial encounters of rings, physical equations that relate the encounters of rings and rolling bodies to forces, a condition for equilibrium of the inner ring taking into consideration the different positions of centers of the outer and inner rings of the bearing. We have identified tangential forces along the rings'rolling tracks, which cause the slippage of rolling bodies in the bearing's loading zone;a formula for determining their values has been derived. The calculation of distribution of load among thebearing's rolling bodies based on the constructed analytical model demonstrates a 5 % decrease in radial forces that act on the central rolling body, and a 3 % increase in radial forces that act on rollers at the edges of thebearing's loading zone compared to known model. That improves the estimated resource of the bearing in terms of contact-fatigue damage to rings and rolling bodies by 18.6 %.

The new analytical model for the distribution of radial load could be applied in the theory of calculation of resource for bearings ofincreased lift capacityin terms of contact-fatigue damage to rings and rolling bodies considering the structure of the separator.

Keywords: load distribution model, bearing's rolling bodies, forcesalong rings'rolling tracks.

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COMPACTION OF POROUS POWDER BODY CONSISTING OF THE ELASTICPLASTIC MEDIUM (p. 44-48)

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In the development of technological processes of producing cold-pressed sintered parts of low porosity, special attention is paid to the mechanism of density variation. In powder metallurgy, a multicomponent charge consisting of plastic metals, as well as poorly compressible inclusions and compounds, is often used. Such charge can equally be attributed to the charge consisting of iron powder, cast iron and glass. In this charge, the first component (base) is ductile iron, and the other two, cast iron and glass, are elastic components. It is of some interest what kind of compaction can be obtained in this case and what resulting equations can be used to estimate the mechanics of compaction of such a powder charge.

The resulting equations of compaction of porous powder bodies of iron-cast iron-glass are proposed. The analysis of the isotropic, rigid-plastic hardening material such as iron-cast iron-glass is given. When compacting such a material, the rate of energy dissipation (pressing pressure) is determined by the rate of volume and form change of the body. It is shown that the difference between compressed (cast iron and glass) and plastic compacted (iron) materials forms special mechanical properties of the matrix. Consequently, hydrostatic pressure can affect the form change of the body, and shear stresses – volume change. The results of the mathematical approach to obtaining the resulting equations of compaction of the elastic-plastic medium showed the way to build a theory of plasticity of the compacted body, which eliminates the need to take into account the type of loading surface. When accounting the loading surface, it is impossible to obtain universal equations of compaction of the porous elastic-plastic medium. It is shown that to apply the classical formulation of the model of the elastic-plastic compacted body, it is necessary to assume that the loading surface is convex-closed

Keywords: loading surface, porous body, resulting equations, iron-cast iron-glass, strain rate, tensor invariant, isotropic material

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DEVELOPMENT OF CONTROL FOR THE ANKLE JOINT SIMULATOR APPLIED TO THE PROBLEM ON VERTICAL POSTURE BALANCE OF A HUMAN (p. 49-57)

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The optimal ankle joint controller based on the model that describes the system of human vertical balance in response to small disturbances was developed. The method for optimization of the selection of control matrices was proposed, which leads to stabilization, taking into consideration the requirements of comfortable return of a human to the equilibrium position, minimization of the efforts of a simulator of the central nervous system (CNS).

With a view to understanding the ways of functioning of the CNS, the operation of its departments responsible for stabiliza-

tion was analyzed, which makes it possible to apply this knowledge to the problem of the balance of the vertical posture. The research is limited to the study of functioning of the ankle joint in terms of its influence on the posture stabilization. The merit of this research is the development of a methodological platform for further simulation of functioning of the ankle, knee and hip joints in totality and determining the optimal choice of the CNS management strategy.

The research supports the hypothesis that at small disturbances in the sagittal plane, the key role in stabilization is played by the ankle joint. The law of the controller management was presented and its model implementation was carried out. To do this, we used the actual values of operating points, obtained based of the program platform of movements tracking Opti Flex Track 13 which simulates human movements in real time.

The results are of value in the process of studying the vertical stabilization of a human. Simulation of operation of different muscle groups taken together is essential for rehabilitation of patients with CNS problems at reduced muscle activity. The results are useful for the design of a functional electrical CNS stimulation controller, development of the technical rehabilitation facilities for people who are at risk of falling.

Keywords: optimal controller, vertical balance of a human, functioning of ankle joint, joint simulator.

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MOTION EQUATIONS OF THE SINGLEMASS VIBRATORY MACHINE WITH A ROTARY-OSCILLATORY MOTION OF THE PLATFORM AND A VIBRATION EXCITER IN THE FORM OF A PASSIVE AUTOBALANCER (p. 58-67)

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This paper describes a mechanical model of the single-mass vibratory machine with a rotary-oscillatory motion of the platform and a vibration exciter in the form of a passive auto-balancer. The platform can oscillate around a fixed axis. The platform holds a multi-ball, a multi-roller, or a multi-pendulum auto-balancer. The auto-balancer's axis of rotation is parallel to the turning axis of the platform. The auto-balancer rotates relative to the platform at a constant angular velocity. The auto-balancer's casing hosts an unbalanced mass in order to excite rapid oscillations of the platform at rotation speed of the auto-balancer. It was assumed that the balls or rollers roll over rolling tracks inside the auto-balancer's casing without detachment or slip. The relative motion of loads is impeded by the Newtonian forces of viscous resistance. Under a normally operating auto-balancer, the loads (pendulums, balls, rollers) cannot catch up with the casing and get stuck at the resonance frequency of the platform's oscillations. This induces the slow resonant oscillations of the platform. Thus, the auto-balancer is applied to excite the dual-frequency vibrations.

Employing the Lagrangian equations of the second kind, we have derived differential motion equations of the vibratory machine. It was established that for the case of a ball-type and a roller-type auto-balancer the differential motion equations of the vibratory machine are similar (with accuracy to signs) and for the case of a pendulum-type vibratory machine, they differ in their form.

Differential equations of the vibratory machine motion are recorded for the case of identical loads.

The models constructed are applicable both in order to study the dynamics of the respective vibratory machines analytically and in order to perform computational experiments.

In analytical research, the models are designed to search for the steady-state motion modes of the vibratory machine, to determine the condition for their existence and stability.

Keywords: inertial vibration exciter, dual frequency vibrations, resonance vibratory machine, auto-balancer, inertial vibratory machine.

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